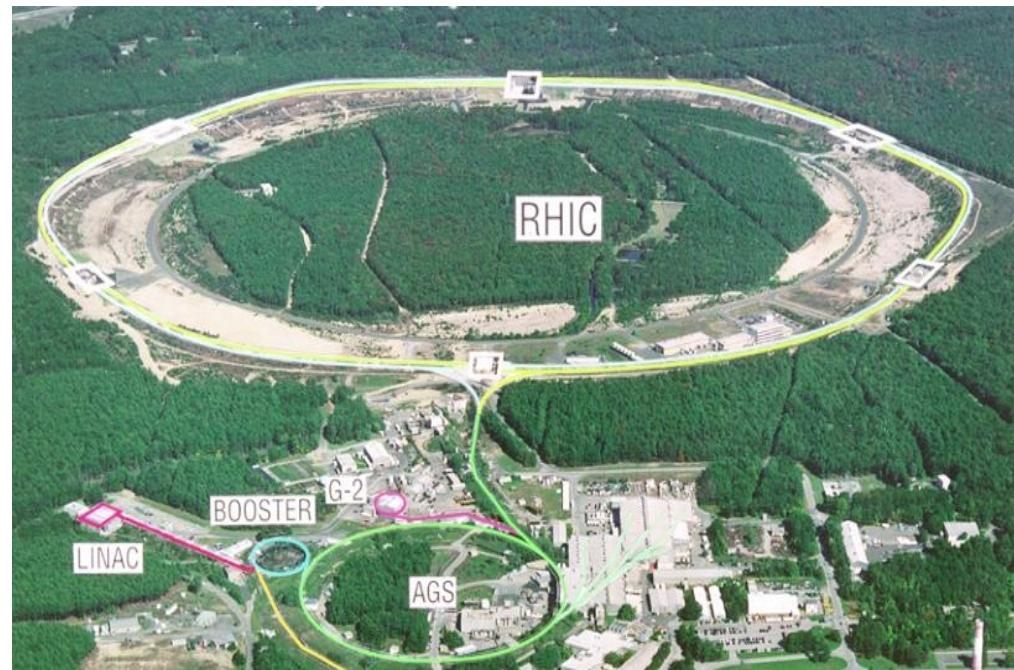


# Helmut's other side: Physics in Bielefeld

Bielefeld



Brookhaven



# 25 years @ BNL

## Lattice QCD Thermodynamics

## & J/psi suppression



Phys. Rev. D34 (1986) 3193

May, 1986

UNIVERSITÄT BIELEFELD

BI-TP 86/16

### CORRELATION AND SCREENING IN FINITE TEMPERATURE SU(2) GAUGE THEORY

K. Kanaya

Institut für Theoretische Physik E  
RWTH Aachen, D-51 Aachen, F.R. Germany

and

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Fakultät für Physik  
Universität Bielefeld, D-48 Bielefeld, F.R. Germany  
and  
Physics Department  
Brookhaven National Laboratory, Upton, NY 11973, USA

#### ABSTRACT

We study the temperature dependence of the correlation length in SU(2) gauge theory around the deconfinement point, using high statistics Monte Carlo simulation on large lattices.



June 1986

Phys. Lett.B178(1986) 416

PHYS. LETT. B, in press

BROOKHAVEN NATIONAL LABORATORY

BNL-38344

### J/ $\psi$ SUPPRESSION BY QUARK-GLUON PLASMA FORMATION

T. Matsui

Center for Theoretical Physics  
Laboratory for Nuclear Science  
Massachusetts Institute of Technology  
Cambridge, MA 02139, USA

and

H. Satz

Fakultät für Physik  
Universität Bielefeld, D-48 Bielefeld, F.R. Germany  
and  
Physics Department  
Brookhaven National Laboratory, Upton, NY 11973, USA

#### ABSTRACT

If high energy heavy ion collisions lead to the formation of a hot quark-gluon plasma, then colour screening prevents  $\psi\bar{\psi}$  binding in the deconfined interior of the interaction region. To study this effect, we compare the temperature dependence of the screening radius, as obtained from lattice QCD, with the  $J/\psi$  radius calculated in charmonium models. The feasibility to detect this effect clearly in the dilepton mass spectrum is examined. We conclude that  $J/\psi$  suppression in nuclear collisions should provide an unambiguous signature of quark-gluon plasma formation.

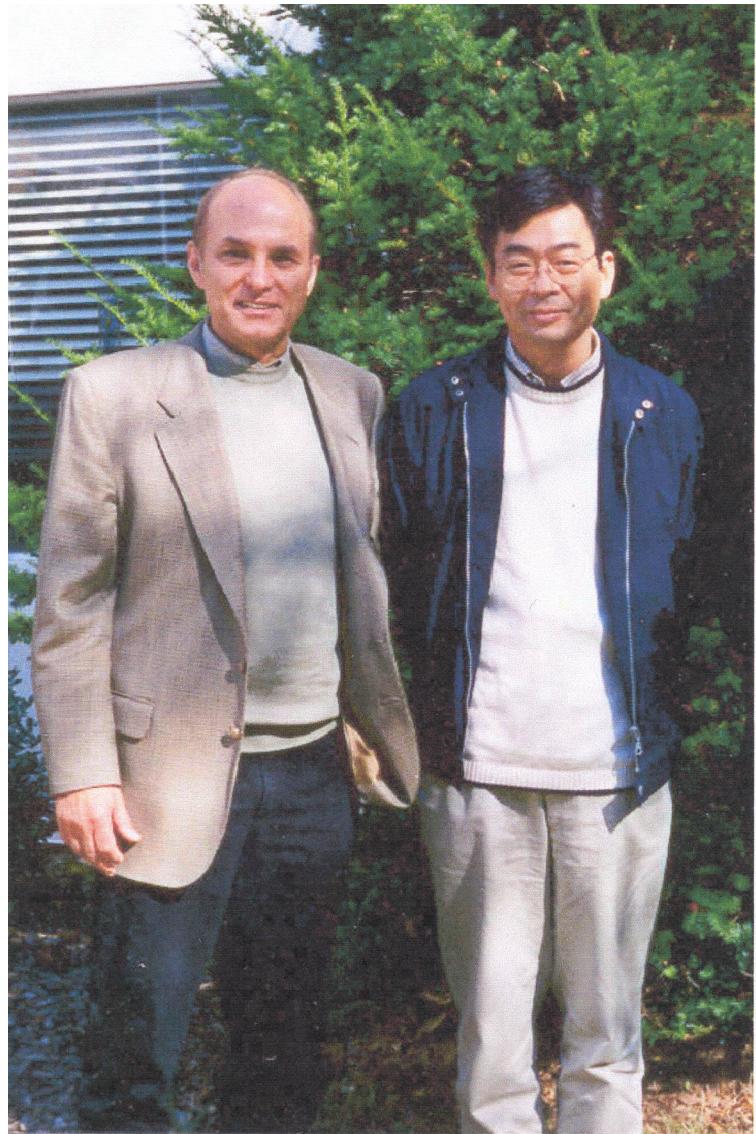
# 25 years @ BNL

Lattice QCD Thermodynamics

&

J/psi suppression

Lattice '86  
conference at  
BNL



Helmut Satz & Tetsuo Matsui

# back to the roots....1977



BI-TP 77/28  
AUGUST 1977

## STATISTICAL CONCEPTS IN HADRON PHYSICS<sup>+</sup>)

H. Satz

Department of Theoretical Physics  
University of Bielefeld  
Germany

# back to the roots....1977



Rolf Hagedorn

BI-TP 77/28  
AUGUST 1977

On a more general level, it is of course also still open if all hadronic systems indeed obey the temperature bound (27), making that relation something of a "fourth law of thermodynamics", or if at sufficiently high energy density a phase transition sets in, from a hadron gas to one of hadronic constituents ("quark gas")<sup>22,23,24</sup>, whose interaction is not governed by the dynamics we have considered here.

#### IV. PHASE TRANSITIONS IN HADRONIC SYSTEMS

The transformation of a hadron gas into a quark gas would in many ways correspond to a conventional phase transition. Since hadrons and their

22) N. Cabibbo, G. Parisi, Phys. Lett. 59B (1974) 67

23) J.C. Perry, M.J. Collins, Phys. Rev. Lett. 34 (1975) 1353

24) B.A. Freedman, L.P. McLerran, MIT preprint 541 (1976)

Larry  
McLerran



# Percolation and Lattice QCD

Volume 97B, number 1

PHYSICS LETTERS

17 November 1980

## A PERCOLATION APPROACH TO STRONGLY INTERACTING MATTER

T. ÇELIK, F. KARSCH and H. SATZ

*Department of Theoretical Physics, University of Bielefeld, Germany*

Received 5 September 1980

Using percolation theory to determine transition points, we show that strongly interacting bulk systems exhibit hadronic matter behaviour for densities  $0.48 n_0 \leq n \leq 14.0 n_0$  and quark matter behavior for  $n \geq 3.84 n_0$ , where  $n_0 = 0.17 \text{ fm}^{-3}$  is nuclear density. For  $3.84 n_0 \leq n \leq 14.0 n_0$ , we find a coexistence region of the two phases.

Volume 101B, number 1,2

PHYSICS LETTERS

30 April 1981

## HIGH TEMPERATURE SU(2) GLUON MATTER ON THE LATTICE

J. ENGELS, F. KARSCH and H. SATZ

*Department of Theoretical Physics, University of Bielefeld, Germany*

and

I. MONTVAY

*II. Institut für Theoretische Physik der Universität Hamburg<sup>1</sup>, Germany*

Received 21 January 1981

We calculate by Monte Carlo simulation on the lattice the energy density  $\epsilon$  of an SU(2) Yang-Mills system at finite physical temperature. First, we study the high temperature form of  $\epsilon$ , showing that the conventional euclidean lattice formulation converges to the parameter-free Stefan-Boltzmann limit of a free gluon gas in the continuum. Secondly, we show that the specific heat of gluon matter exhibits a sharp peak at the transition point from the confined phase to the color-screened gluon gas. The resulting transition temperature is found to be  $210 \pm 10$  MeV.

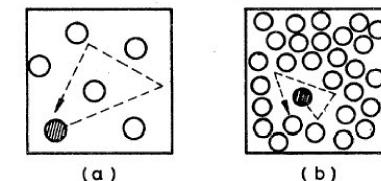


FIG. 4. Particle mobility in a dilute (a) and in a dense (b) system.

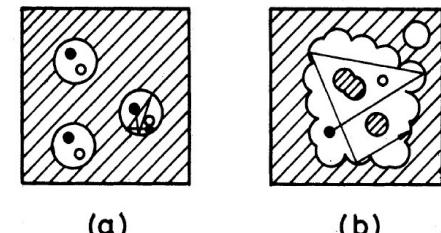


FIG. 2. Quark mobility at (a) low and at (b) high density.

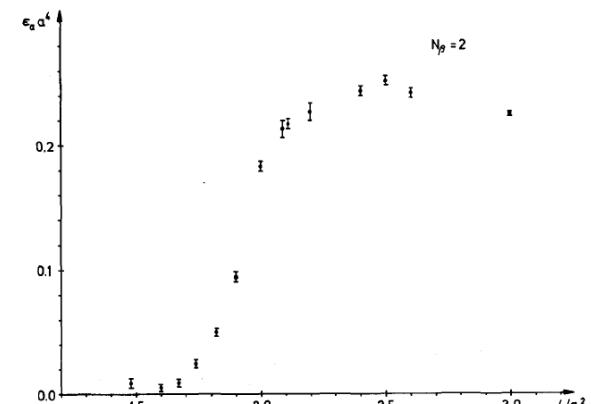
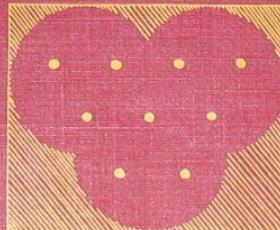


Fig. 3. Energy density of gluon matter versus  $4/g^2$ , at fixed lattice size  $N_\beta = 2$ , after about 500 iterations.

# Center for Interdisciplinary Research, August 1980

## Statistical Mechanics of Quarks and Hadrons



Edited by H. Satz  
North-Holland

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# Center for Interdisciplinary Research, August 1980

## *Statistical Mechanics of Quarks and Hadrons*



Edited by H. Satz  
North-Holland

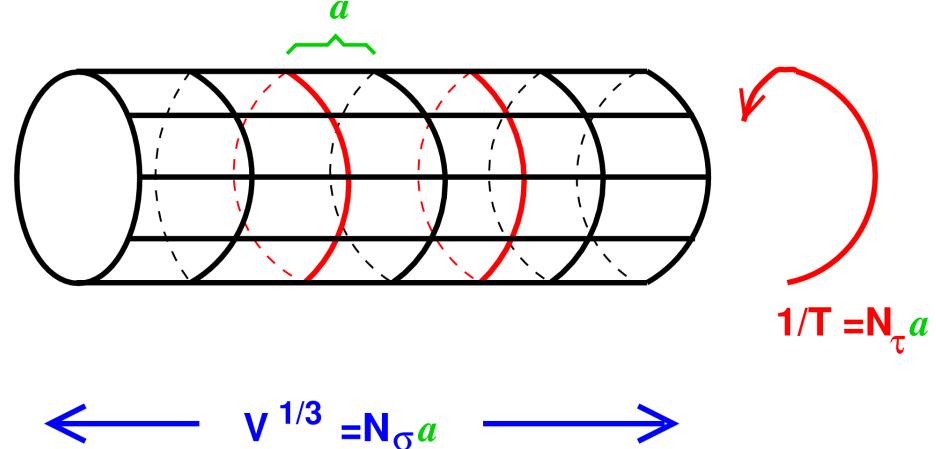
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# Analyzing hot and dense matter

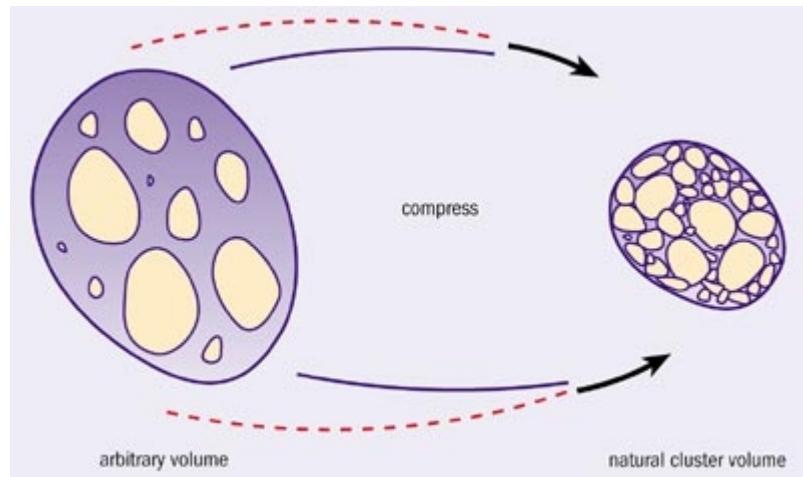
Statistical QCD & lattice



1980/81



Statistical Bootstrap & percolation



TR440: 800 KFlops

Statistical concepts in hadron physics:  
This task, the formulation of statistical hadron physics, can be approached in classical fashion along two different lines..  
(H. Satz, 1977)

# Making Bielefeld – the Metropolis of Lattice QCD thermodynamics



Bielefeld university

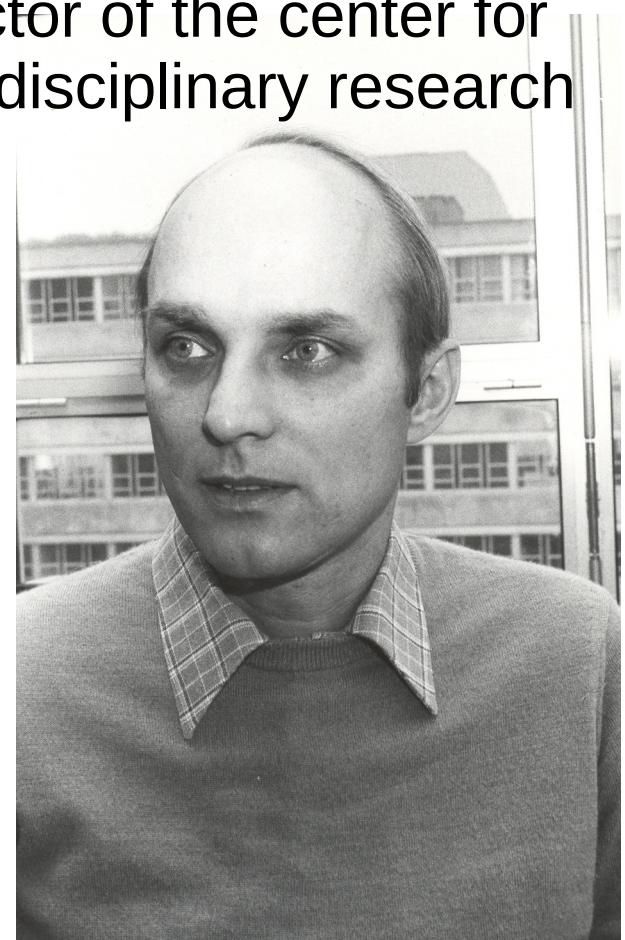
~ 1980

# Making Bielefeld – the Metropolis of Lattice QCD thermodynamics



Bielefeld university

director of the center for  
interdisciplinary research



the 1980 idea:

use the **Metropolis** algorithm to  
simulate strongly interacting matter

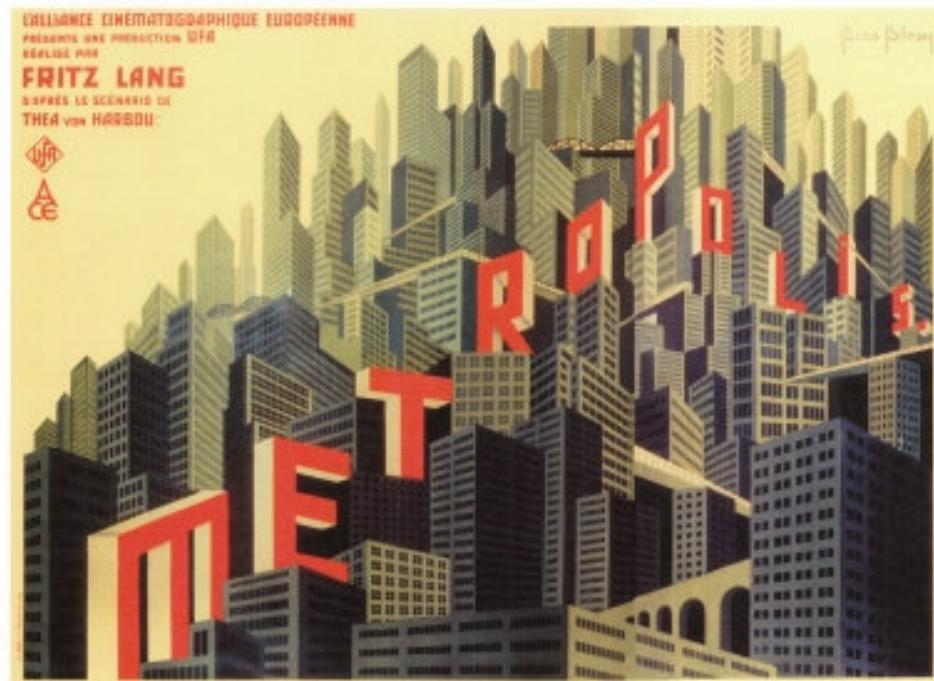
# Making Bielefeld – the Metropolis of Lattice QCD thermodynamics



Bielefeld university

the 1980 idea:

use the **Metropolis** algorithm to  
simulate strongly interacting matter



# Bielefeld – the Metropolis of Lattice QCD thermodynamics



Bielefeld university

Then he went the way he wanted to go, to find the answers.....

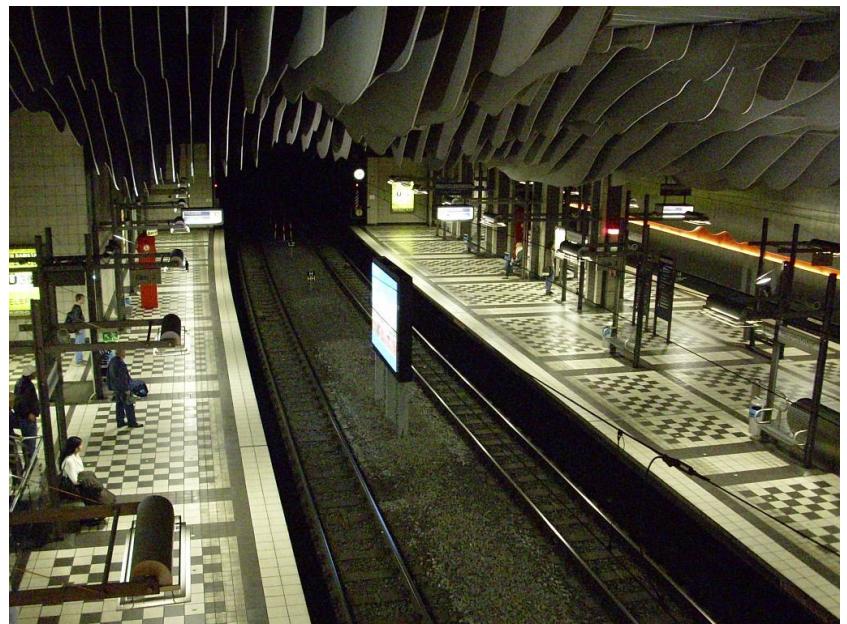


# Bielefeld – the Metropolis of Lattice QCD thermodynamics



Bielefeld university

Then he went the way he  
wanted to go, to find the  
answers....down the steps  
which led to the lower structure  
of the New Tower of Babel  
(=Bielefeld?)

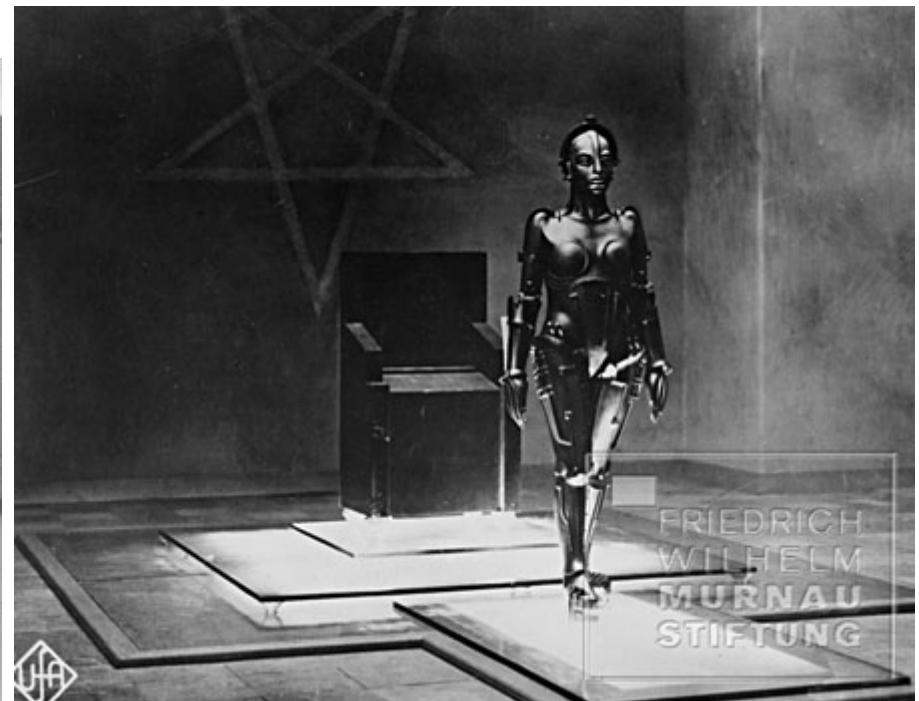


# Bielefeld – the Metropolis of Lattice QCD thermodynamics

the Telefunken machine



machine man



...confined to an underground city of their own...

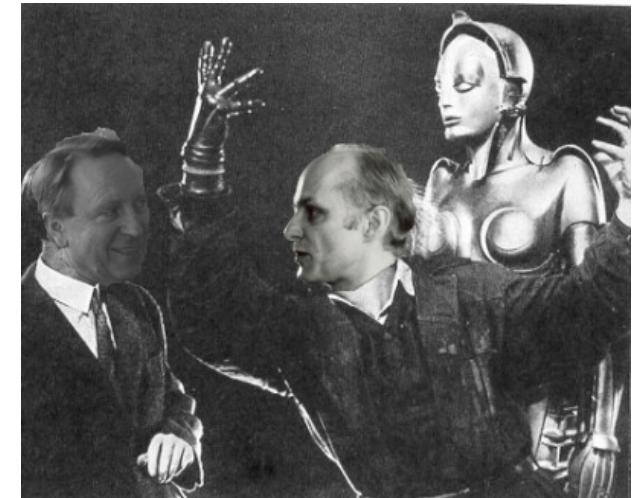
[where]...

all machines, machines, machines confined to their pedestals...

lived their god like lives

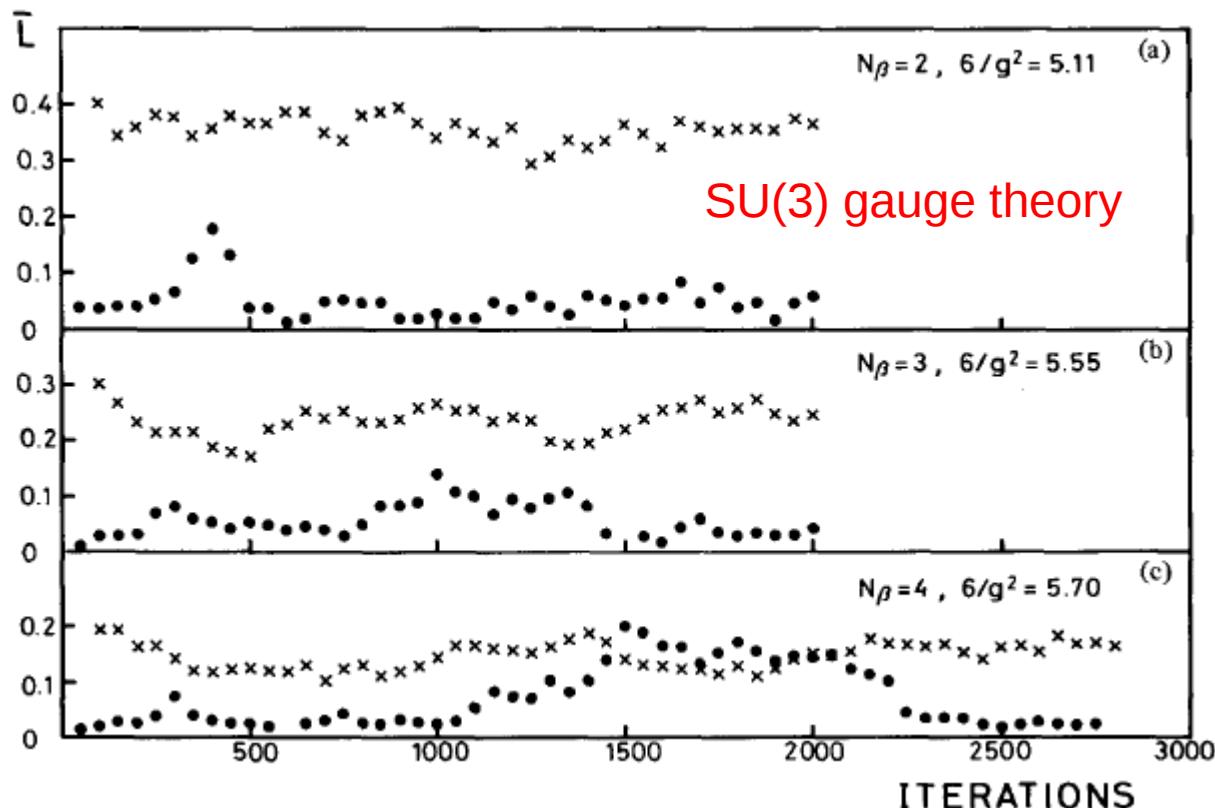
# Helmut and his task force

"I can't help them," said the brain,  
"nobody can help them. They are  
where they must be....



# Appearance and disappearance of phase transitions

A first order phase transition !



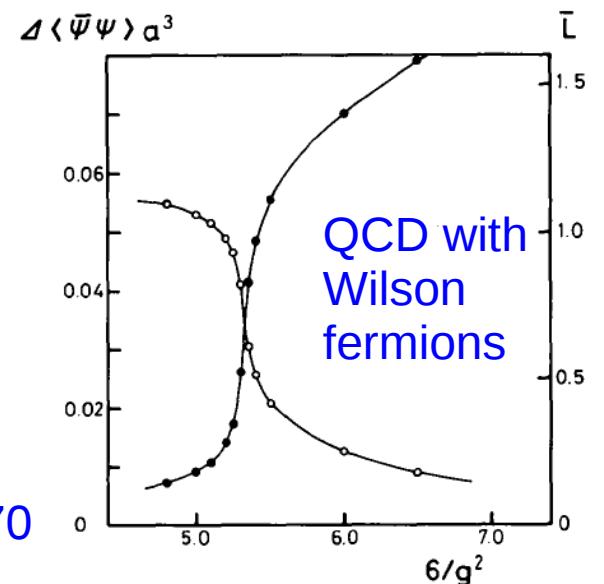
T. Celik, J. Engels, H. Satz, Phys. Lett. 125B (1983) 411

T. Celik, J. Engels, H. Satz, Nucl. Phys. B256 (1985) 670



Tarik Celik

A rapid crossover !



# (Part of) Helmut's family



ARCTIC SCHOOL OF PHYSICS 1982

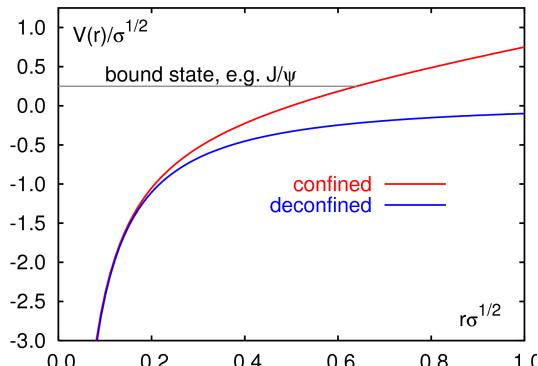
AS-HOTELL



# A signature for deconfined matter J/psi suppression

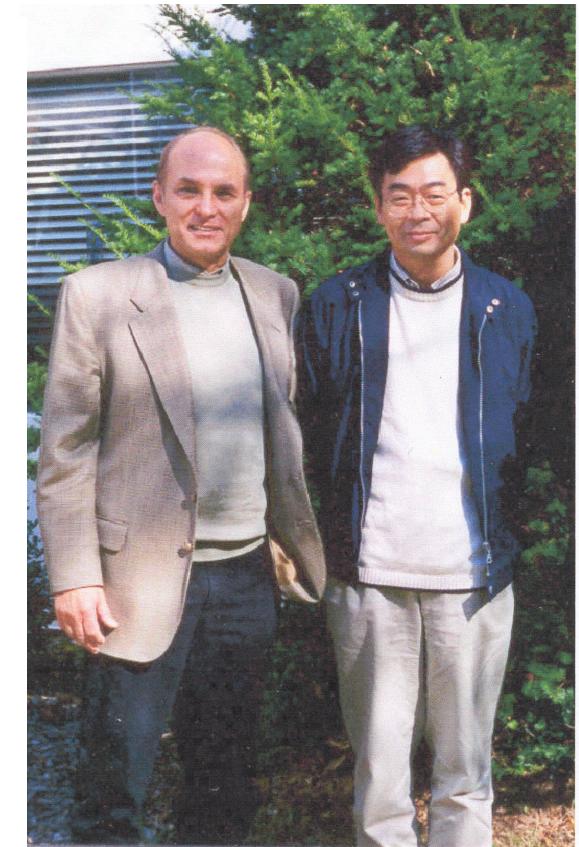
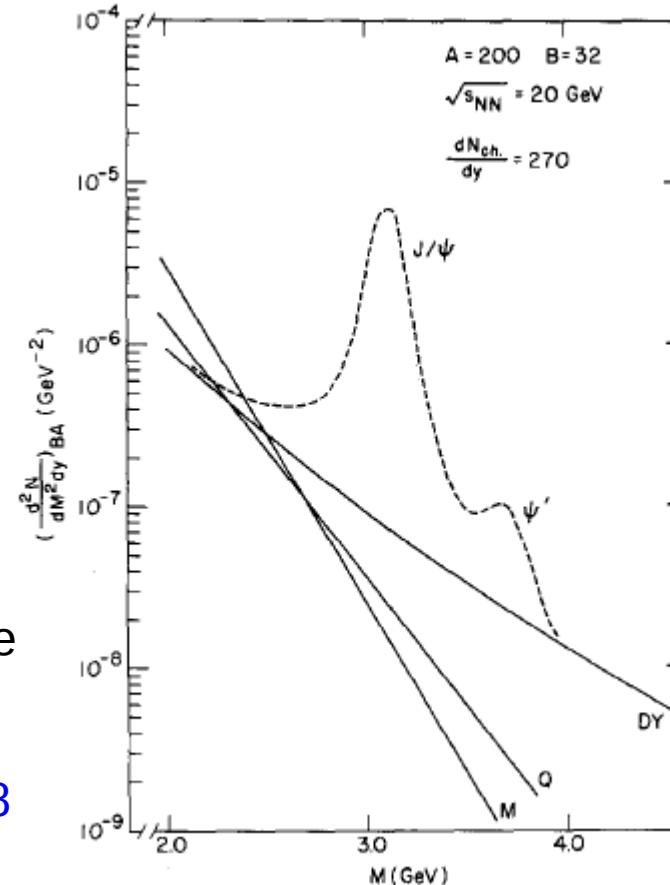
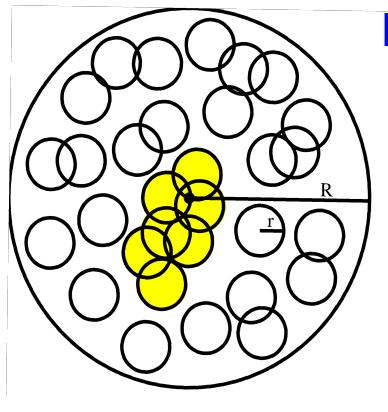
color screening leads to deconfinement

Matsui&Satz '86



deconfinement sets in when the string density within a cluster reaches a critical value

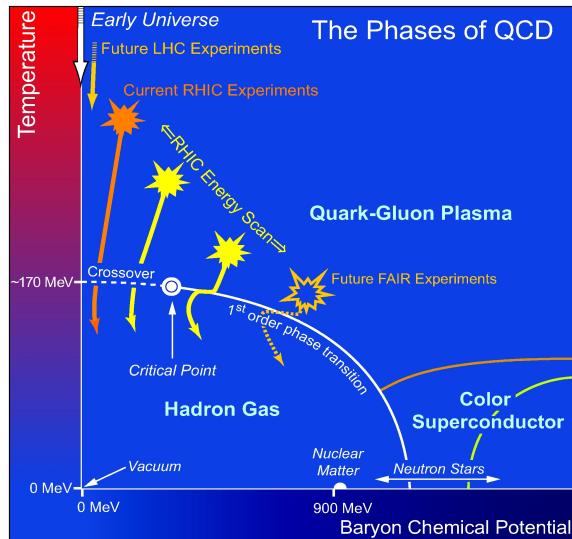
Nardi&Satz '98



Satz - Matsui

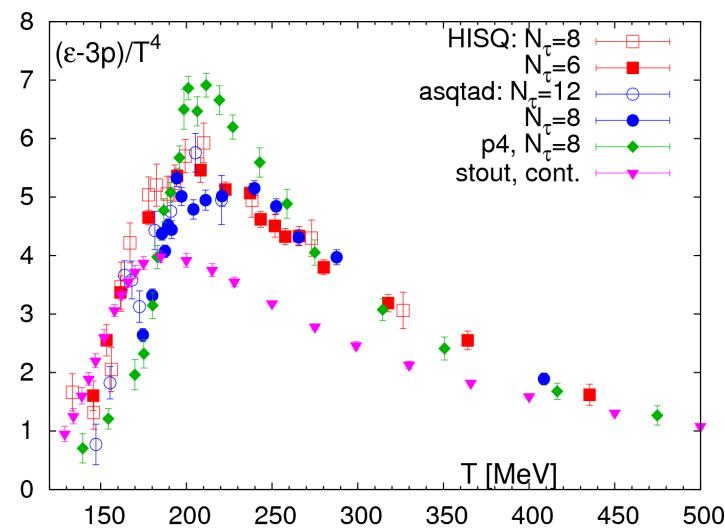
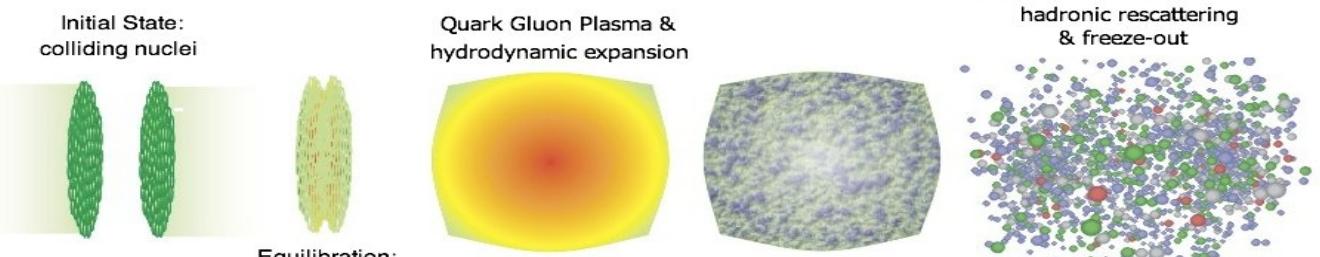
If high energy heavy ion collisions lead to the formation of a hot quark-gluon plasma, then colour screening prevents  $c\bar{c}$  binding...

# QCD Thermodynamics and Heavy Ion Collisions



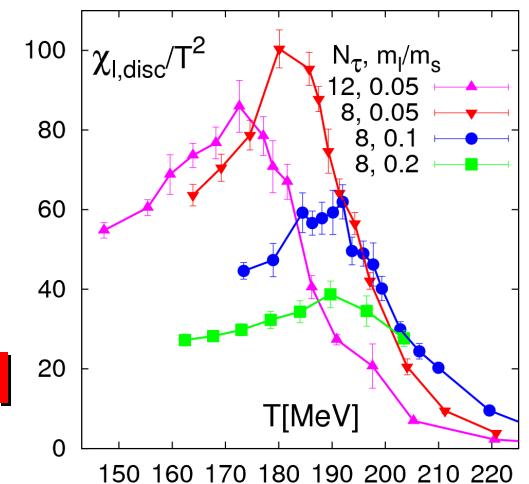
Equation of State  
&  
transition temperature

HotQCD, 2009+preliminary

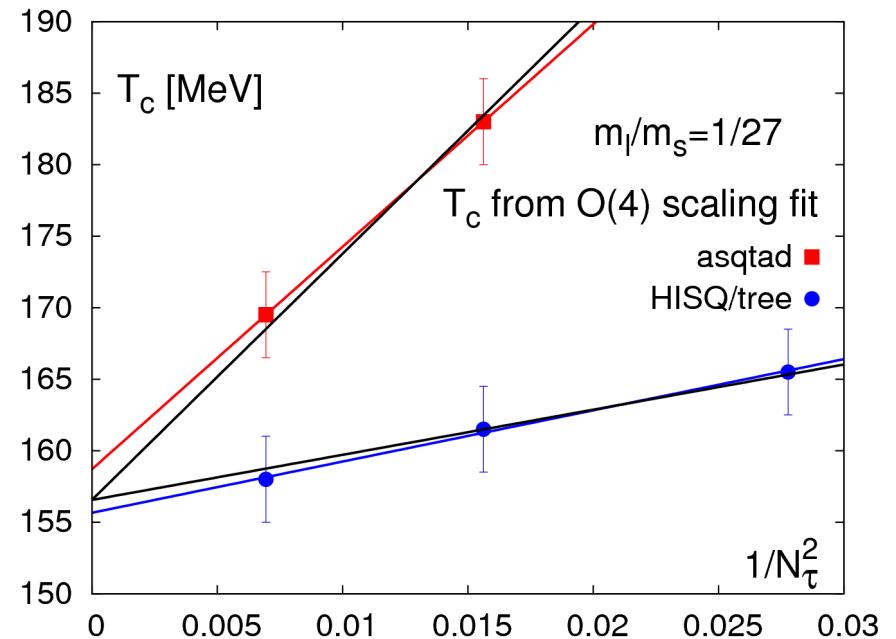
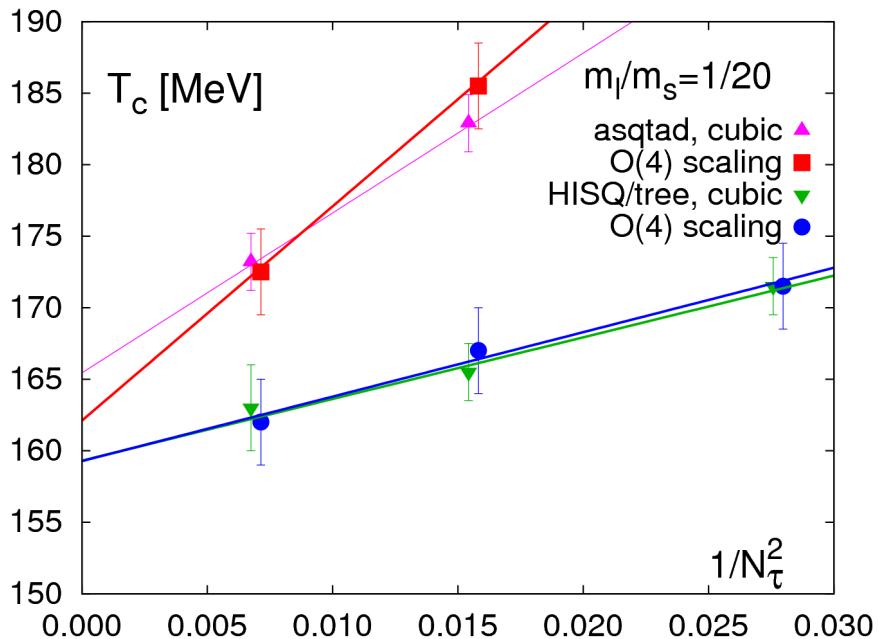


energy density &  
pressure

disconnected  
part of the chiral  
susceptibility



# The QCD (phase) transition temperature



hotQCD collaboration preliminary:

$$T_c = (157 \pm 4 \pm 3 \pm 1) \text{ MeV}$$

# A signal for the QCD transition charge fluctuations

quark number susceptibilities

on the freeze-out curve:

J. Cleymans et al., PRC 73, 034905 (2006)

$$T(\mu_B) = a - b\mu_B^2 - c\mu_B^4$$

$$\mu_B(\sqrt{s_{NN}}) = d/(1 + e\sqrt{s_{NN}})$$

e.g.:

$$\frac{\chi_{B,\mu}^{(3)}}{\chi_{B,\mu}^{(1)}} = \frac{\chi_{B,0}^{(4)} + \frac{1}{6}\chi_{B,0}^{(6)}(\mu_B/T)^2 + \dots}{\chi_{B,0}^{(2)} + \frac{1}{6}\chi_{B,0}^{(4)}(\mu_B/T)^2 + \dots}$$

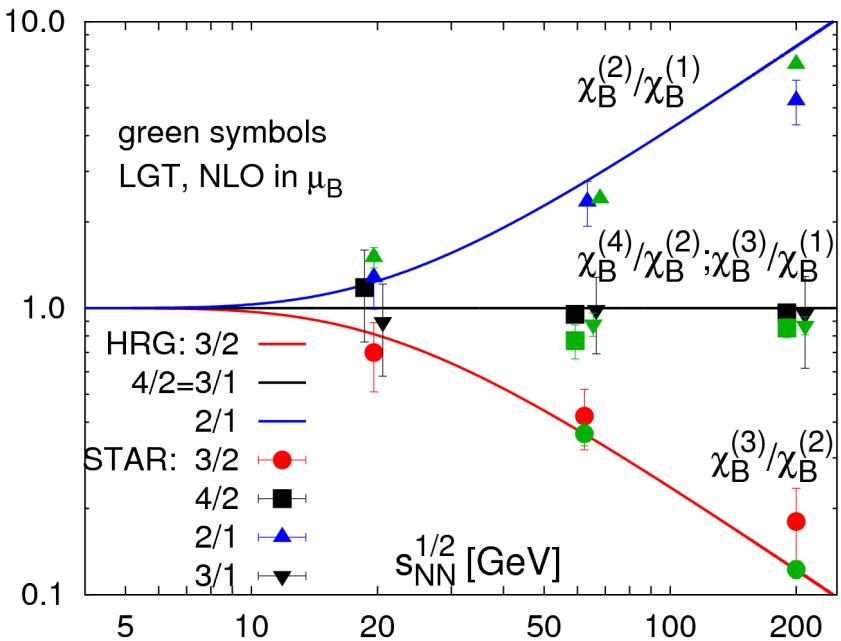
susceptibilities = cumulants of charge fluctuations

$$\delta N_B = N_B - \langle N_B \rangle$$

$$\chi_{B,\mu}^{(2)} = \langle (\delta N_B)^2 \rangle$$

$$\chi_{B,\mu}^{(4)} = \langle (\delta N_B)^4 \rangle - 3\langle (\delta N_B)^2 \rangle^2$$

Cumulants of B-charge fluctuations



HRG(lines): FK, K Redlich, PL B695 (2011) 136

lattice (green): C. Schmidt, arXiv:1007.5164

Experiment: STAR: arXiv:1004.4959

B-charge fluctuations at freeze-out are at present consistent with HRG model predictions and lattice calculations, BUT.....  $\chi_B^{(6)}$

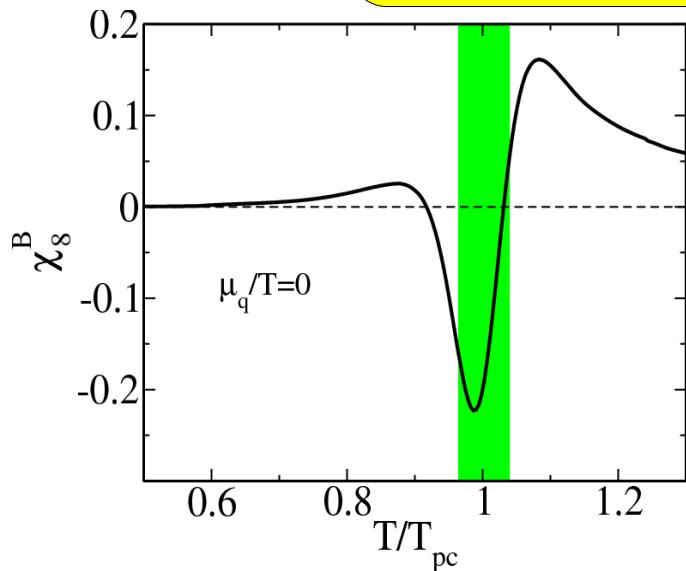
# Higher moments of charge fluctuations at RHIC and LHC

higher cumulants (e.g. 6<sup>th</sup> order) are drastically different in QCD close to criticality and in a hadron resonance gas, e.g.

$$\frac{\chi_{B,\mu}^{(6)}}{\chi_{B,\mu}^{(2)}} = \begin{cases} = 1 & , \text{hadron resonance gas} \\ < 0 & , \text{QCD at the crossover transition} \end{cases}$$

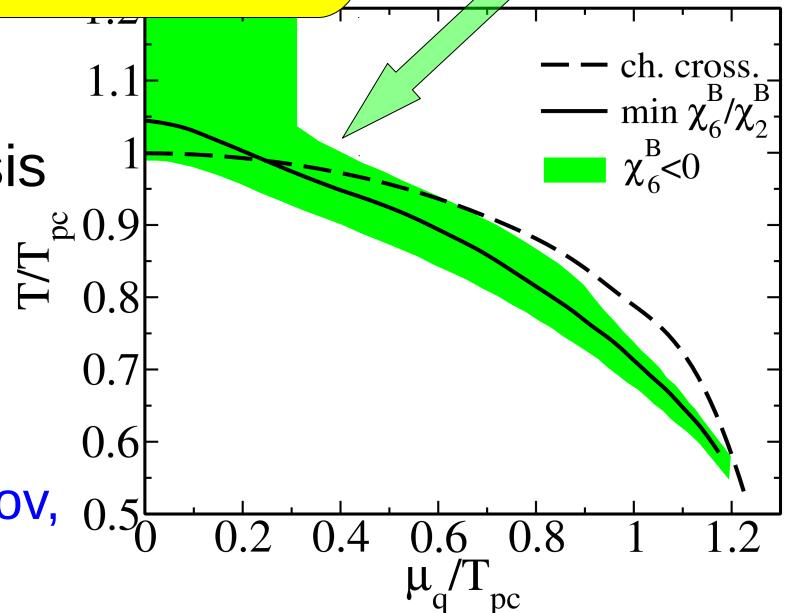
$$\chi_{B,\mu_B}^{(6)} = \chi_{B,0}^{(6)} + \frac{1}{2} \chi_{B,0}^{(8)} \left( \frac{\mu_B}{T} \right)^2 + \dots$$

$$\chi_B^{(6)}(\mu_B) < 0$$



PQM model  
FRG analysis

B. Friman, FK,  
K. Redlich, V. Skokov,  
arXiv:1103.3511;



# Happy anniversaries



# The future will show ....



this is not the eRHIC construction side!

# Hall of fame

# Hall of fame

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W http://de.wikipedia.org/wiki/Helmut\_Satz

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W Helmut Satz - Wikipedia +

Anmelden / Benutzerkonto erstellen

Artikel Diskussion Lesen Bearbeiten Versionsgeschichte Suche

## Helmut Satz

**Helmut Satz** (\* 13. April 1936 in Berlin) ist ein deutscher theoretischer Physiker, der sich mit der [Gitterreichtheorien](#) und [Quantenchromodynamik](#) beschäftigt.

Satz studierte an der [Michigan State University](#) und der [Universität Hamburg](#), wo er 1963 promovierte und sich 1967 habilitierte (Über die statistische Beschreibung hochenergetischer Vielteilchenerzeugungsreaktionen). Danach war er unter anderem in [Los Angeles](#), am CERN in Genf und in Helsinki. Satz ist seit 1971 Professor für Theoretische Physik an der [Universität Bielefeld](#), wo er – zuletzt Dekan des Fachbereichs – 2001 emeritierte. 1974 bis 1981 war er im Direktorium des Zentrums für Interdisziplinäre Forschung der Universität Bielefeld. Außerdem war er Gastwissenschaftler am [Brookhaven National Laboratory](#) (BNL, 1985 bis 1989) und am [CERN](#), wo er 1989 bis 1995 beurlaubt von der Universität Bielefeld die Schwerionenstoss-Experimente als Theoretiker betreute.

Satz befasste sich insbesondere mit der Physik des [Quark-Gluon-Plasmas](#) (QGP), das bei [Schwerionenstößen](#) untersucht wird und der Zustand der Materie in der Anfangszeit des Universums war. Der Phasenübergang vom Hadronengas zum Quark-Gluon-Gas findet nach Simulationen mit Gitterreichtheorien bei etwa  $10^{12}$  Grad Kelvin statt. Das Universum befand sich etwa eine Milliardstel Sekunde nach dem Urknall für etwa 10 Mikrosekunden in diesem Zustand, bevor die Hadronen kondensierten. Beim Nachweis des QGP in Schwerionenstößen ist man auf verschiedene Signaturen angewiesen, die zusammen indirekt Hinweise auf das QGP geben, eine davon stammt von Satz und Tetsuo Matsui 1986<sup>[1]</sup>, die Unterdrückung der Bildung von  $J/\Psi$  Teilchen (gebundene Zustände schwerer Quarks, hier aus Charm und Anticharm Quarks), da diese im Quark-Gluon-Plasma bildlich gesprochen zu "schmelzen" beginnen. Aufgrund solcher Signaturen wurde 2000 am CERN der Nachweis des Quark-Gluon Plasmas bekanntgegeben. Weitere Versuche mit noch höheren Energien werden am [RHIC](#) im BNL und am [LHC](#) des CERN ausgeführt.

In Bielefeld simulierte er mit seinen Mitarbeitern (wie [Frithjof Karsch](#), der bei ihm 1982 promovierte) auch Quark-Gluon-Plasmen mit Hochleistungs- Parallelrechnern, die dort auch speziell für die Simulation in der QCD entwickelt wurden. 1992 bis 1997 koordinierte die Universität Bielefeld dabei das EU-Netzwerk [Computational Particle Physics](#) (und dessen Nachfolger [Phase Transitions in Hot Matter](#)) und spielte darin eine führende Rolle. Satz ist als Mitglied der Europäischen Rechner-Gremien für Kernphysik NuPECC und Elementarteilchenphysik ECFA an der Planung von Hochleistungsrechner-Zentren beteiligt.

1979 bis 1986 war er Herausgeber der [Zeitschrift für Physik C](#).

### Schriften [Bearbeiten]

- Herausgeber mit Sourav Sarkar, Bikash Sinha: [The physics of the quark-gluon plasma- introductory lectures](#), Springer 2009
- [Satz States of Matter in QCD, 2009](#)
- Herausgeber: [Statistical mechanics of quarks and hadrons](#), North Holland 1981 (Symposium an der Universität Bielefeld 1980)

Diese Seite wurde zuletzt am 13. April 2011 um 19:35 Uhr geändert.